higher velocity. It will also be observed that ammonium nitrate itself under a powerful initial impulse gives rise to a notable pressure, so that that ingredient is not to be looked on as a diluent of the T.N.T., but as an explosive substance, as well as a purveyor of the oxygen in which T.N.T. is deficient.

Smoke.—For the purpose of correct ranging and locating the position of burst, an explosive developing smoke is desirable. Amatol 80/20, when used alone, had the disadvantage that it gave no smoke, as the products of the detonation are colourless gases, thus:—

$$2C_7H_3N_3O_6+21NH_4NO_3=24N_2+47H_2O+14CO_2;$$

whereas, when picric acid or trinitrotoluene detonates, a large quantity of unconsumed carbon is set free, affording a black cloud useful for the purpose of observation.

Mixtures capable of producing a white smoke, useful for aerial observation, were then added, and as a result of investigations as to the best method of securing its dissociation, ammonium chloride in conjunction with the ingredients of amatol was localised at the base of the filling.

Needless to say, there were many other developments in explosives practice during the war, but the example of the train of detonation leading up to the complete detonation of a high explosive shell was chosen to exemplify the subject of this discourse, since it included many features and new problems which had an intimate connection with the technical development of the subject.

To secure the high percentage of detonations that our artillerists obtained with the freedom from prematures which they always demanded, it was necessary to have each part of the somewhat complicated train as nearly perfect as possible not only in design, in order to withstand the effects of rough usage and of set-back in the gun, but also in workmanship, both mechanical and chemical as to purity of materials. This was achieved by the co-ordination of a large number of industries organised on a scientific basis, and these were becoming every day more and more efficient. War is now so highly organised that for its successful prosecution all the technical industry of the country is brought under requisition, and to succeed requires a higher development in research, applied methods, and industrial progress than belongs to the enemy.

The effort made by this country in the time of stress to overcome deficiencies in these respects was successful as a great technical achievement, and should be an encouragement to us to look forward to an equal development of our scientific industries under the stress of a competitive peace.

Stellar Parallax.[1]

By SIR FRANK DYSON, F.R.S.

IN the past ten years a number of the large telescopes of the world have been applied to the determination of stellar parallax. The principle of the method is well known and is extremely simple, merely consisting in the detection of the small annual movement of a near star with reference to more distant stars caused by the different position occupied by the observer in consequence of the earth's annual revolution round the sun. The whole difficulty consists in the extreme minuteness of the angle to be measured. If two railway lines, starting at King's Cross, instead of remaining parallel, met at Newcastle the angle between them would be of the order of the angle to be measured in finding the distances of the nearest stars. To form an idea of what is now being done by large telescopes using photographic methods, imagine two plumb-lines 5 ft. apart. They are sensibly parallel, but actually meet at the centre of the earth, and the angle between them is 0·05″. An angle of this size is measured with an accuracy of ±0·01″. Results of this high value were first obtained by Prof. Schlesinger at the Yerkes Observatory. At the present time the observatories of Allegheny, Greenwich, McCormick, Mount Wilson, Yerkes, and a number of others are engaged on a comprehensive programme. At Greenwich we determine the parallaxes of fifty stars a year; at some of the American observatories many more.

Necessarily, a good deal of care is required both in taking the photographs and in measuring them. The image of a star may have a diameter of 2″ or 3″, and the position of its centre should be measurable to between 1/50th and 1/100th of this amount. The methods of measurement present some points of interest which need not be described now, but a word or two about the precautions to be observed in taking the photographs may be of interest. The images must be as circular and uniform as possible. (1) The guiding of the telescope must be as perfect as possible. (2) The lenses of large object-glasses must be adjusted with great care so that there may be neither tilt nor eccentricity between them. (3) Photographs should all be taken with the telescope pointing in the same direction. One cannot be taken when the field is east and another when it is west. Atmospheric dispersion and possibly minute flexure of the lenses cause slight deformation of the images which may be scarcely visible to the eye, but appear in measures. (4) The star the parallax of which is being determined and the comparison stars should have approximately

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[1] From a discourse delivered at the Royal Institution on Friday, April 29.

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equal images on the photograph. This is secured by means of a rotating shutter, a neutral screen, or the use of a grating in front of the objective.

The purpose of (3) and (4) is to make any residual errors the same for the parallax star and the comparison stars, and so far as possible the same on all photographs.

The knowledge of the distance of a star gives us immediately its luminosity or the amount of light it emits as compared with the sun. There is a very great range in luminosity even for stars of the same spectral type. Now the stars have been arranged in an order according to the spectra, which agrees fairly well with their order in colour from blue to red, and is essentially an arrangement according to temperature. This may be regarded as an extremely good first approximation to a classification of stellar spectra. But it does not detect any differences attributable to absolute luminosity, though presumably density and gravity at the surface layer of the star from which the lines in the spectrum have their origin must be widely different.

A few years ago a very fruitful investigation was commenced at Mount Wilson by Adams and Kohlschuter. By a close comparison of the spectra of stars of the same spectral class, but differing greatly in absolute luminosity, they detected lines the intensities of which differ. Adams and his coadjutors at Mount Wilson have pursued this research with very great success. They have found in stellar spectra a number of pairs of neighbouring lines, one line of each pair being independent of the absolute luminosity, while the other changes in intensity with the luminosity of the star. They have measured the relative intensities of these pairs of lines, and compared their measures with the luminosities of 650 stars already known through the trigonometrical determinations of parallax made at Allegheny, McCormick, Mount Wilson, and Yerkes. Thus they have found the luminosities of stars corresponding to different intensities of the lines. They have recently published a catalogue (*Astrophysical Journal,* March, 1921) giving the luminosities and parallaxes of 1680 stars.

The advantage of this method is that it extends the range of parallax determinations beyond the limit (say) 0·02″ of the trigonometrical method, the limit of the spectroscopic method being determined only by the capacity of large telescopes to give measurable spectra. In the table a comparison is given with unpublished results at Greenwich obtained by the trigonometrical method:—

No.	App. mag. m.	Mag. at 10 parsecs m.	Parallax Mount Wilson ″	Parallax Greenwich ″
B 1673	5·6	4·2	0·052	0·034
B 2897	6·1	4·3	0·044	0·040
B 2971	7·8	7·2	0·076	0·088
C 1604	8·2	4·9	0·022	0·015
B 3983	6·9	5·7	0·058	0·052
B 4181	5·0	1·7	0·022	0·041
B 4234	6·4	2·4	0·016	0·013
C 2242	7·6	5·4	0·036	0·046
B 4322	4·8	3·6	0·058	0·031
B 5009	4·8	3·8	0·158	0·171
B 6129	6·6	6·7	0·105	0·076

Comparison of these results, obtained by entirely different methods, shows the accuracy of 20 per cent. claimed for Mount Wilson, and ±0·010″ for Greenwich is reached.

A third method is being employed extensively for determining stellar distances depending on the fact that the masses of stars lie within very restricted limits. It is applicable only to double stars, and depends on Kepler's third law, $M+m=a^3/P^2$, where M, m are the masses, a is the mean distance between the components, and P the period of a double star. When P is known and $M+m$ assumed, a is found, and, further, as the cube root of $M+m$ is involved, an error in the assumed mass produces a much smaller error in the mean distance. Now the *angular* mean distance is determined by direct observation for all double stars the orbits of which can be calculated. At the present time this amounts to more than 150. But it has been shown by Hertzsprung and Russell that for double stars which have completed too small a portion of their orbits for their periods to be known it is still possible to obtain their "hypothetical" parallax with considerable probability. The method has been recently applied at Greenwich to obtain the parallaxes of a large number of stars, and the accordance with the results found by the trigonometrical and spectroscopic methods is very satisfactory (see a paper in Monthly Notices R.A.S., November, 1920, by Messrs. Jackson and Farmer).

I believe there is in preparation by American astronomers a catalogue giving the parallaxes of 3000 stars, about half of which have been determined by two at least of these three methods. We may expect that in the course of a very few years the distances of all stars visible to the naked eye in the northern hemisphere will have been determined, as well as those of many fainter stars. This great accession of knowledge of stellar distances carries with it a corresponding increase with reference to the luminosities, sizes, masses, densities, and velocities of stars of different spectral classes.

Obituary.

WILLIAM WARDE FOWLER. 1847–1921.

WARDE FOWLER, like Arthur Sidgwick, was one of the men we can least spare—a classical scholar of distinction and a writer of great charm who sympathised warmly with the aims and methods of science, and strove to give them a larger place in the life of his University. It would scarcely be possible to gain a clearer insight into the strength and weakness of an Oxford education as it was nearly twenty years

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